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SOME SILKWORM MOTH REFLEXES.

VERNON L. KELLOGG.

Silkworm moths, *Bombyx mori*, are sexually mature and eager to mate immediately on issuing from the pupal cocoon. They take no food (their mouth parts are atrophied), they do not fly, they are unresponsive to light ; their whole behavior, in fact, is determined by their response to the mating and egg-laying instincts. We have thus an animal of considerable complexity of organization, belonging to a group of organisms well advanced in the animal scale, in a most simple state for experimentation.

The female moth, nearly immobile, protrudes a paired scent-organ from the hindmost abdominal segment, and the male, walking nervously about and fluttering its useless wings, soon finds the female by virtue of its chemotactic response to the emanating odor. Males find the females exclusively by this response, but orient themselves for copulation (after reaching the female) by contact. When two males accidentally come into contact in their moving about they try persistently to copulate.

A male with antennæ intact, but with eyes blackened, finds females immediately and with just as much precision as those with eyes unblackened. A male with antennæ off and eyes unblackened does not find females unless by accident in its aimless moving about. But if a male with antennæ off does come into contact, by chance, with a female it always (or nearly so) readily and immediately mates. The male is not excited before touching the female, but is immediately and strongly so after coming in contact with her. Males with antennæ on become strongly excited when a female is brought within several inches of them.

The protruded scent-glands of the female are withdrawn into the body immediately on her being touched by a male. If the scent-glands are cut off and put wholly apart from the female, males are as strongly attracted to these isolated scent-glands as they are to un mutilated females ; on the contrary they are not at all attracted to the mutilated females. If the cut-out scent-glands are put by the side of and but a little apart from the

female from which they are taken, the males always neglect the near-by live female and go directly to the scent-glands. Males attracted to the isolated scent-glands remain by them persistently trying to copulate with them, moving excitedly around and around them and over and over them with the external genitalia vainly trying to seize them.

The behavior of males with the antenna of only one side removed is striking. A male with left antenna off when within three or four inches of a female (with protruded scent-glands) becomes strongly excited and moves energetically around in repeated circles to the right, or rather in a flat spiral thus getting (usually) gradually nearer and nearer the female and finally coming into contact with her, when he is immediately controlled by the contact stimulus. A male with right antenna off circles or spirals to the left. It is a curious sight to see two males with right and left antenna off, respectively, circling violently about in opposite directions when the immobile female a few inches removed protrudes her scent-glands. This behavior is quite in accordance with Loeb's explanation of the forward movement of bilaterally symmetrical animals.

The results of all the experiments tried show how rigorously the male moths are controlled by the scent attraction (chemotropism) and how absolutely dependent mating (the one adult performance of the males) is on this reaction. If we can find specialized animals in a condition where all attractions and repulsions (stimuli) but one are eliminated we may readily perceive the rigorous control exercised by this remaining one. We are, unfortunately, in the general circumstances of animal life too much limited to the use of very simply organized animals for reaction and reflex experimentation. This tends to make it difficult to carry over to the behavior of complexly organized animals the physico-chemical interpretation which is steadily gaining ground as the key to the understanding of the springs and character of the behavior of the simplest organisms. But where the complex stimuli and reactions that determine the behavior of complexly organized forms can be isolated and studied the inevitableness of much of this behavior can be recognized.

Reflexes of Moths Without Cephalic and Thoracic Ganglia.—

A number of experiments was made to determine the need, or absence of need, of the principal ganglia of the central nervous system in the performance of the two chief reflexes in the silkworm moth's life, viz., mating and egg-laying.

Males mate with headless females, and the headless females, after mating, lay a few eggs which develop normally, that is become fertilized by the release of spermatozoa from the spermatheca in the female's body, are oviposited by the repeated extrusion and retraction of the ovipositor, and make the usual color changes (from yellow to cherry-red and then to lead-gray) incidental to normal development. But in no case did a headless female lay her full complement of eggs, in fact in no case were more than a score of eggs laid (the normal number is from 200 to 350). Headless females (and headless males) usually live as long as unmutated individuals, *i. e.*, from a week to two weeks.

Females with head and thorax cut off (and even part of the abdomen) can be mated with by males, and this fractional part of the female can fertilize and oviposit a few eggs which begin normal development. In one case 10 eggs, of which 8 are now normally developing were oviposited by such an impregnated part of female abdomen, this abdominal relict remaining alive (!), *i. e.*, flexible and responsive to stimulus and capable of extruding the ovipositor and laying eggs, for forty hours.

Males with head removed cannot find females, nor can they mate if placed in contact with them. When the head or head and prothorax of a male is cut off immediately after the male and female are *in copulo* the female, although uninjured, lays no eggs. If heads of both males and females *in copulo* are removed no eggs are laid although both moths remain alive usually as long as do unmutated individuals.

A silkworm moth can maintain itself right side up with antennæ off or with antennæ off and eyes blackened, but with head off one position seems indistinguishable from another to it, *i. e.*, it lies on one side or the other, on the venter or dorsum equally willingly. The organs of equilibrium are not on the antennæ, then, but are lost when the rest of the head is removed.

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